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(54) Arc Welding Device

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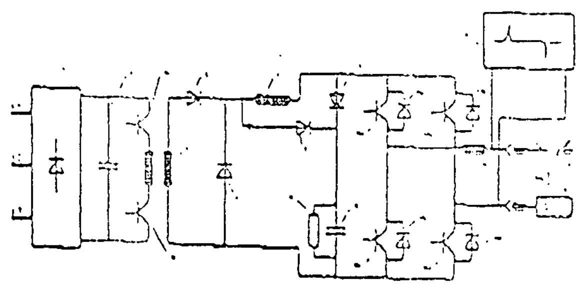
(57) The invention concerns an arc welding device consisting of an inverter current source with a line-voltage-powered rectifier 1, an intermediate circuit 2, a current transformer 4 that is cycled at the input end and a rectifier 5 on the secondary end of current transformer 4 plus a power inverter that receives power from the inverter

current source and at whose output a welding electrode 15, 16 is inductively connected. To permit use at a high amperage with a high degree of protection against unacceptable voltage surges, the inverter that is inductively coupled to the inverter current source is designed as a bridge circuit, where a semiconductor switch 12a-12d with a free-wheeling diode 13a-13d connected in parallel is provided in each of its four bridge diagonals, and a safety circuit 9, 10, 11 is provided for the inverter so the cut-off voltages on semiconductor switches 13a-13d can be set at a predetermined voltage level during the commutation phase.



Description

The invention concerns an arc welding device consisting of an inverter current source with a line-voltage-powered rectifier, an intermediate circuit, a current transformer that is cycled at the primary or input end and a rectifier on the secondary or output end of the current transformer plus an inverter that is supplied with power by the inverter power source and has a welding electrode connected inductively to its output.

Such an arc welding device is known from the prior art according to German Patent 3,803,447, where an inverter circuit is connected to the inverter power source of this known welding device and consists essentially of two controllable semiconductor

switches. The semiconductor switches are switched by a control device in such a way that a current with a frequency between 50 and 500 Hz flows in the welding electrode. In addition, the known circuit has a double-throw switch at the output of the inverter whose first position permits d.c. operation and whose second position allows a.c. operation. Although the known circuit has the advantage that it is easy to switch from d.c. operation to a.c. operation and vice versa, it has been found in practice that the double-throw switch must have a comparatively expensive design, especially at a high output current.

Therefore, the object of this invention is to improve on an arc welding device of the type characterized initially such that the mechanical switch can be eliminated.

This object is achieved according to this invention by the fact that the inverter that is inductively coupled to the inverter current source is designed as a bridge circuit which has at each of its four bridge diagonals a semiconductor switch with a free-wheeling diode connected in parallel, and a protective circuit is provided for the inverter so the cut-off voltages for the semiconductor switches can be set at a predetermined voltage level during the commutation phase.

This invention is characterized in that a high amperage can be made available for the welding process by using a known inverter in a bridge circuit. At the same time, reverse-current circuits are built up due to the free-wheeling diodes in parallel with the semiconductor switches of the individual bridge diagonals so the magnetic energy stored in the inductive load at the start of the respective commutation phases can be dissipated. The safety circuit provided for the inverter assures that the cut-off voltage applied to the individual semiconductor switches is limited to a preset level, so destruction of the semiconductor switches due to higher voltage is prevented. On the other hand, the adjustability of the voltage level assures that the welding process will be maintained. In a.c. welding a new trigger pulse must be delivered by a suitably triggered high-voltage pulse generator after each zero crossing of the current. For the ionization of the arc due to the triggering pulse to be maintained over a long period of time, the inverter must at this time supply an output voltage higher than the operating voltage used in the welding process outside the commutation phases. Due to the safety circuit according to this invention, the voltage level at the inverter output can be set high enough at the time of ionization to maintain the electric arc but at the same time

not exceed the cut-off voltage of the semiconductor switches.

A simple design of the circuitry is obtained when the protective circuit consists of a series connection of a current valve connected in parallel with the feeder points of the power inverter and a capacitor on which a predetermined voltage level is impressed.

According to a preferred embodiment, the predetermined voltage level for limiting the cut-off voltage on the semiconductor switches is formed by connecting a variable d.c. voltage source in parallel with the capacitor. As an alternative, a current source may also be used to charge the capacitor.

In a variant of the circuit that is especially simple to implement, the peak voltage in the amount of 80 V, for example, applied at the output of the rectifier on the secondary side of the inverter current source is applied to the capacitor instead of the variable d.c. voltage source.

A practical implementation of the power inverter consists of having the components in the individual bridge diagonals formed by semiconductor switches with integrated parallel diodes.

Within the scope of this invention, it is also conceivable to use a current source of the traditional type instead of an inverter current source, in which case the line voltage may be rectified by a full-wave bridge rectifier.

This invention is explained in greater detail below with reference to figures, which show the following:

Figure 1 shows a first embodiment of the invention;

Figure 2 shows a second embodiment of the invention;

Figure 3 shows a third embodiment of the invention; and

Figure 4 shows level diagrams of the welding voltage U_s, the welding current I_s and the high-voltage pulse of the ignition device.

Figure 1 shows a rectifier 1 that draws power from a three-phase network **L1**, **L2**, **L3** and in turn powers a capacitor that forms an intermediate circuit and supplies power to a downstream current transformer 4. The current transformer 4 is cycled at the primary end by semiconductor switches 3a, 3b such that a clock frequency in the middle frequency range of 25-60 kHz, for example, is obtained at the input end.

At the secondary end, the current transformer 4 is connected to a rectifier diode 5 where a free-wheeling diode 6 is connected in parallel with the series connection of the secondary winding of current transformer 4 and rectifier diode 5. The circuit

described here is a so-called inverter current source that supplies direct current to the part of the circuit described below.

A smoothing reactor 7 with a downstream power inverter is provided to smooth the output current of the inverter current source. The power inverter is formed by a bridge circuit consisting of four semiconductor switches **12a** through **12d** that may be designed in the form of transistors, for example. One free-wheeling diode 13a through **13d** is connected in parallel with each semiconductor switch **12a** through 12d. The welding process represented by welding electrode 15 and ground terminal **16** is connected at the output of the power inverter. A high-voltage pulse generator 19 that delivers a high-voltage pulse at the start of the welding process and after each zero pass of the welding current is connected in parallel with the power rectifier output. A blocking diode 14 is connected in series in order to isolate the high-voltage pulses from the inverter output.

A series connection of a current valve 9 and a capacitor **10** is connected in parallel with the input terminals of the power inverter, where an ohmic resistor 11 is connected in parallel with capacitor **10**. An auxiliary diode 8 is connected at the common terminal of current valve 9 and capacitor 10 and its other terminal is at the output of the inverter current source.

The function of the circuit illustrated in Figure 1 is explained below with reference to the level diagrams in **Figure 4**.

To supply an alternating current I_s of the desired alternating frequency such as 50 to 500 Hz to the welding process 15, 16, the semiconductor switches **12a** through 12d are cycled accordingly at their base terminals such that in a first switch position, the diagonal of the inverter formed by semiconductor switches 12a and **12d** carries a current and the diagonal formed by semiconductor switches **12b** and **12c** is currentless (**Figure 4**, upper plateau of I_s). In this phase the current flows from the inverter current source through smoothing reactor 7, semiconductor switch **12a**, inductance 14, welding process **15, 16** and across semiconductor switch **12d**.

During the second half wave of the alternating current (lower plateau of I_s in **Figure 4**), the bridge diagonal formed by semiconductor switches **12b** and **12c** carries a current and the bridge diagonal formed by semiconductor switches 12a and **12d** is currentless. Therefore, in the second half wave, current flows from the inverter current source across smoothing reactor 7, semiconductor switch **12b**, the welding process 15, 16 inductance

14 and semiconductor switch **12c**.

The commutation, i.e., the transition from one bridge diagonal to the other, then takes place such that first the previously closed semiconductor switches 12a, 12d or **12b, 12c** are opened, and after the commutation time has elapsed, the semiconductor switches of the bridge diagonal which then carries a current are closed. At the time when commutation begins, magnetic energy is therefore stored in inductances 14 and 7 and is dissipated as follows during the commutation phase with the circuit according to this invention.

After opening the previously closed semiconductor switches **12a**, **12d**, the welding current that was previously closed in inductance 14 then flows further across free-wheeling diode **13b**, current valve 9, capacitor 10 and free-wheeling diode **13c**.

After the previously closed switches 12b, 12c are opened, the welding current flows across free-wheeling diode 13a, current valve 9, capacitor 10 and free-wheeling diode 13d.

The magnetic energy stored in inductance 7 is dissipated via the circuit formed by elements 9, 10, 6.

In this period of time, during which the equalizing current induced by the stored magnetic energy is flowing, a constant d.c. voltage is consistently applied to capacitor 10. This is due to the fact that a d.c. voltage corresponding to the no-load output voltage of the current transformer 4 on the secondary side is impressed on capacitor 10 via auxiliary diode 8. As a result of impressing this d.c. voltage level, the output voltage U_{I0} (see top diagram in **Figure 4**) at the time of the ignition pulse (diagrammed in the bottom part of the chart) of the power inverter is fixed at a certain level such as 80 V, which is above the operating voltage UB (e.g., 20 V) output by the inverter outside the commutation time. This elevated voltage level is sufficient to maintain the electric arc after ignition. On the other hand, impressing the d.c. voltage level assures that cut-off voltage on semiconductor switches 12a through 12d belonging to the respective reverse-current loop is limited to the voltage level applied to capacitor 10. Exceeding the allowed cut-off voltage due to the transient phenomena caused by the load inductance 14 is thus effectively prevented.

The ohmic resistor 11 connected in parallel with the terminals of capacitor 10 serves to convert the energy discharged from inductance 7 and/or 14 into capacitor 10.

The circuit according to this invention thus makes it possible to use power inverters with arc welding equipment while

making the arc welding process more secure, but without inadmissably high cut-off voltages destroying the semiconductor switches in the power inverter diagonals.

The second embodiment of this invention illustrated in **Figure 2** differs from the embodiment illustrated in **Figure 1** only in that instead of auxiliary diode 8, a variable d.c. voltage source **17** is provided and is connected in parallel with the terminals of capacitor **10** and the ohmic resistor 11 via an isolating diode **18**. Thus a d.c. voltage is also impressed on capacitor 10, and here again the value of the impressed d.c. voltage limits the cut-off voltage applied to semiconductor switches **12a** through 12d provided in the respective loop. Due to the variability of d.c. voltage source 17, the impressed capacitor voltage is not dependent on the output of the secondary terminal of the current transformer 4 in contrast with the embodiment illustrated in **Figure** 1. The other advantages are also retained. Finally, the embodiment of the invention illustrated in **Figure** 3 differs from that in **Figure** 2 in that instead of a voltage source, there is a constant current source 17 that supplies power to the protective circuit formed by elements 9 and 10 via another isolating diode 21. The constant current source **17** supplies a charging current to capacitor **10** such that the capacitor maintains the charge corresponding to the predetermined voltage level. In contrast with the embodiment according to **Figure 2**, the charging current is supplied via the additional isolating diode 21 to the terminal point of the inductance 7 facing the power inverter.

Patent Claims

1. Arc welding device consisting of an inverter current source with a rectifier (1) that is supplied with line voltage, with an intermediate circuit (2), a current transformer (4) that is cycled at the primary end and with a rectifier (5) located on the output end of the current transformer (4) and with a power inverter that receives power from the inverter current source and has a welding electrode (15, 16) inductively connected at its output, characterized in that the power inverter inductively connected to the inverter current source is designed as a bridge circuit, where one semiconductor switch (12a-12d) with a free-wheeling diode (13a-13d) connected in parallel with the semiconductor switch is provided in each of the four bridge diagonals of the bridge circuit, and the power inverter is provided with a protective circuit (9, 10, 11) by means of which the cut-off voltages on the semiconductor switcher (13a-13d) during the commutation phase can be set at a predetermined voltage level.

2. Arc welding device according to Claim 1, characterized in that the inverter current source contains two alternately switched current transformers on the input end.

3. Arc welding device according to Claim 1 or Claim 2, characterized in that the protective circuit is formed by a series circuit that is connected in parallel with the feeder points of the power inverter and consists of a current valve (9) and a capacitor (10) on which the predetermined voltage level is impressed.

4. Arc welding device according to Claim 1, 2 or 3, characterized in that the predetermined voltage level is formed by a d.c. voltage source, especially a variable d.c. voltage source.

5. Arc welding device according to Claim 1, 2 or 3, characterized in that the predetermined voltage level is formed by an auxiliary diode (8) that is connected to the common terminal point of the current valve (9) and the capacitor (10) and at its second terminal it is connected to the output of the rectifier (5) on the output end of the current transformer (4).

6. Arc welding device according to Claim 1, 2 or 3, characterized in that the predetermined voltage level is formed by a d.c. current source (20)that charges the capacitor (10).

7. Arc welding device according to one of the preceding claims, characterized in that each semiconductor switch is designed with its parallel free-wheeling diode integrated into it.

8. Arc welding device according to one of the preceding claims, characterized in that a traditional current source with a full-wave rectifier powered by line voltage is used instead of the inverter current source.

Plus 4 pages of drawings

ZEICHNUNGEN SEITE 1

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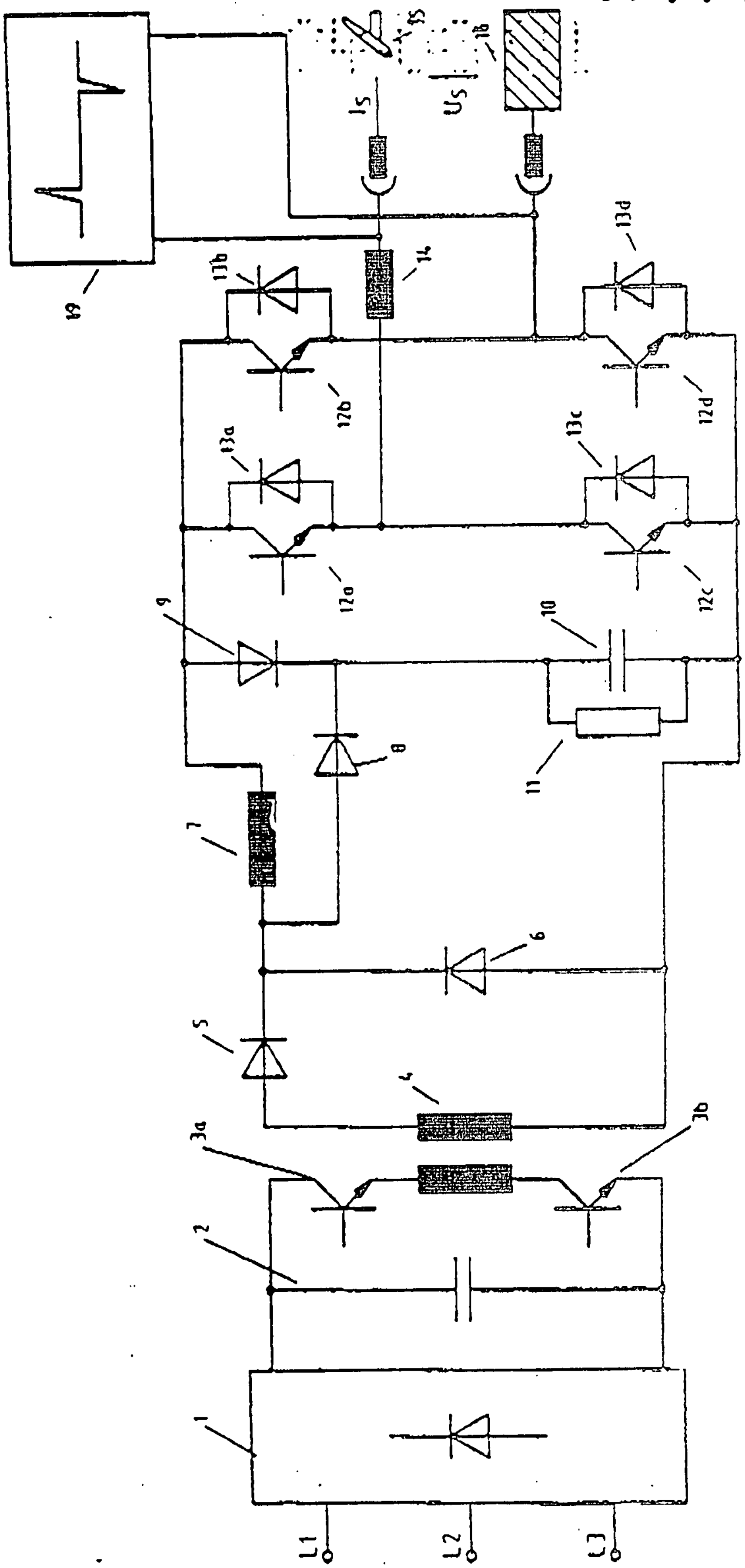

Fig. 1

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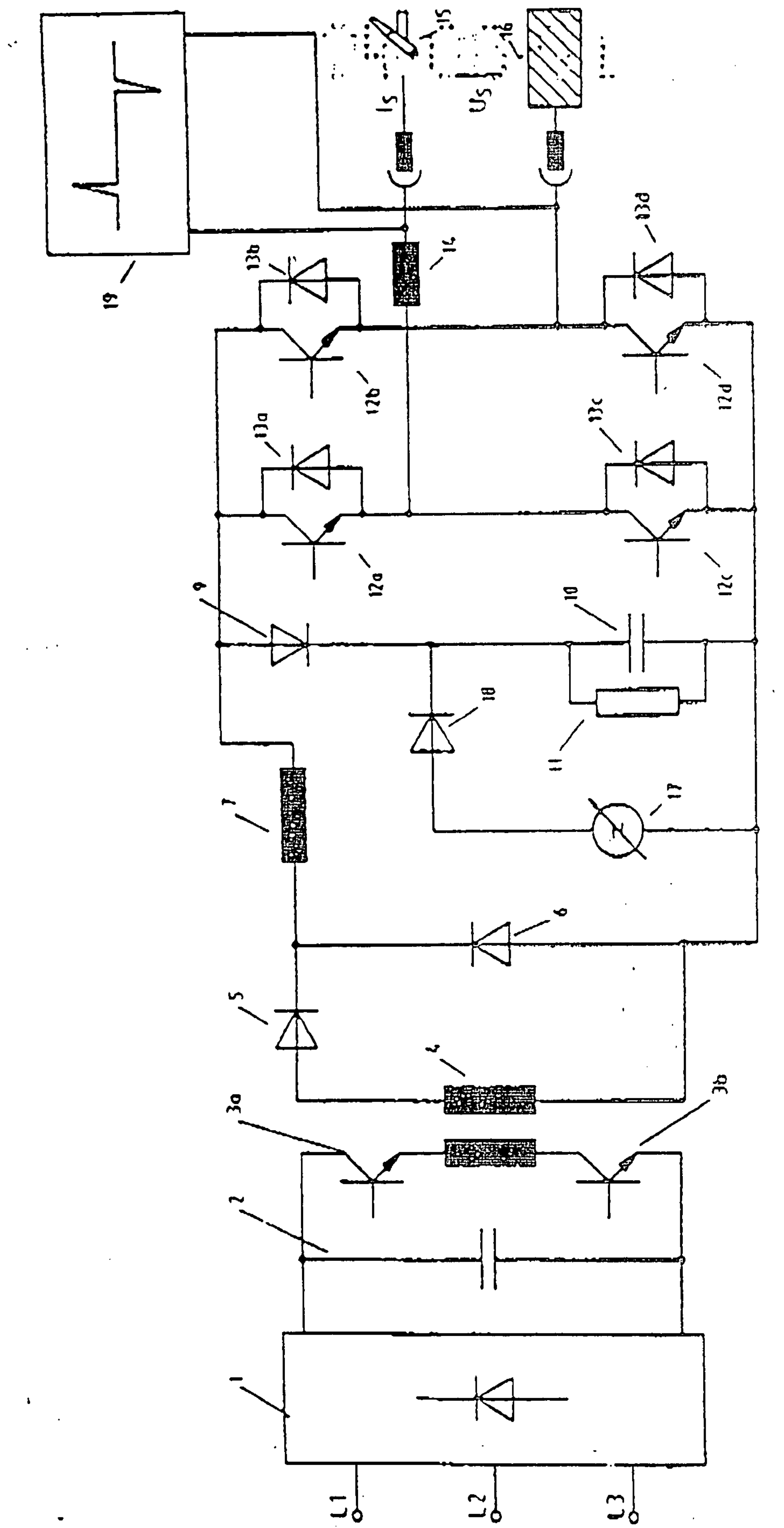

Fig. 2

ZEICHNUNGEN SEITE 3

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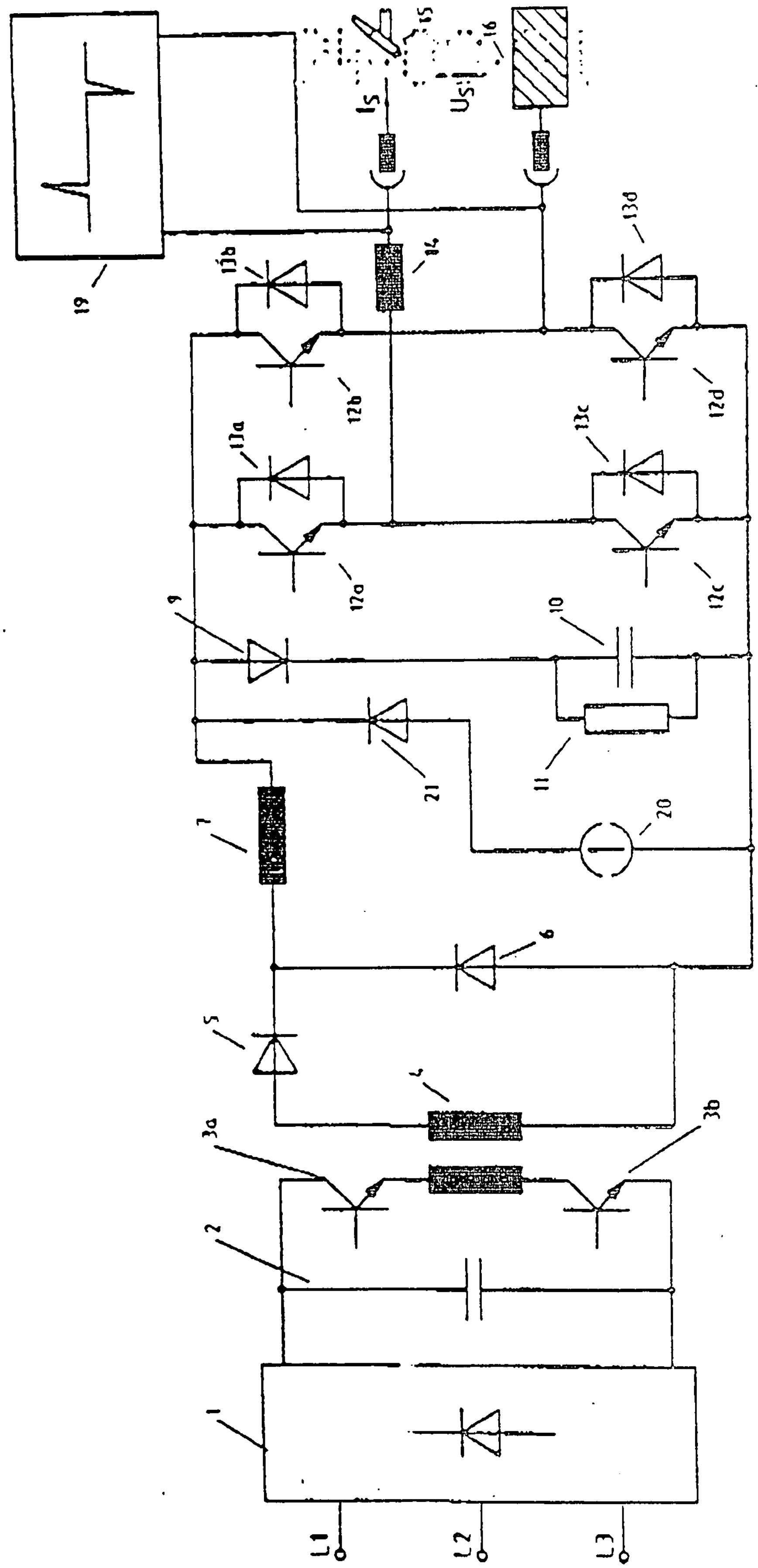

Fig. 3

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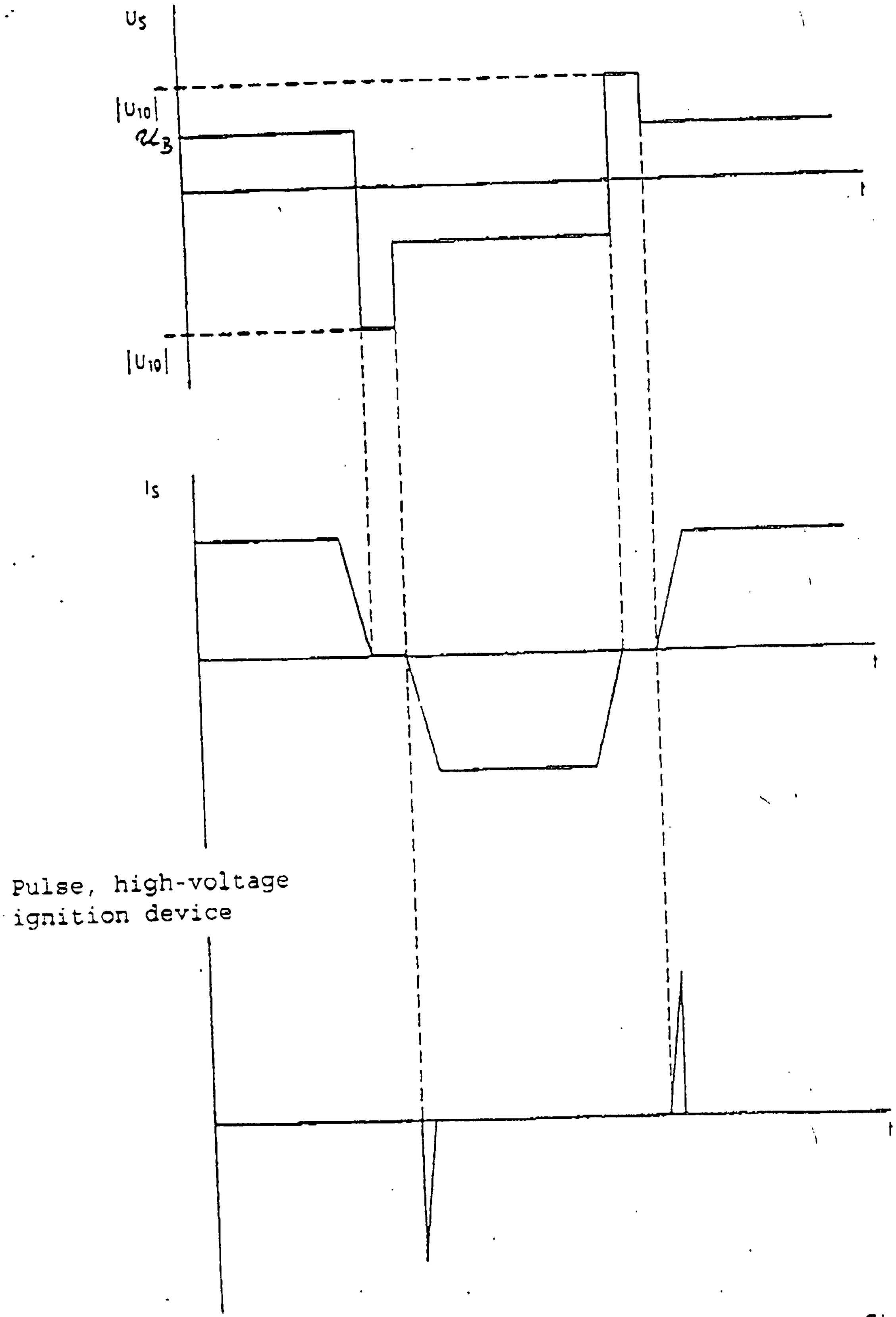

Fig. 4